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Theoretical and experimental investigations of two-photon lasing and inversionless lasing have been completed. Continuous-wave two-photon lasing has been demonstrated for the first time and its predicted bistable character verified. The role of pump bandwidth in the production of inversionless gain has been studied and the maximal efficacy of narrow bandwidth of pumps identified. Continuous-wave lasing in a Cascade-type three-level atomic system has been observed.

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Experimental Studies of Fundamental One- and Two-Photon Lasing Processes

Final Report

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STATEMENT OF THE PROBLEM STUDIED

Laser action is of interest as a fundamental physical process and because of its widespread importance in technology. The present project has been directed toward enhancing basic understanding of several newly discovered forms of laser action. One of these is laser action based on two-photon stimulated emission. In two-photon laser gain, the gain medium transfers energy to the light field via the simultaneous emission of photon pairs. The individual photons within a pair are highly correlated in time. Two-photon gain is non-linear and leads to qualitatively different laser performance particularly in the case of threshold. The concept of inversionless laser gain has recently become popular. In this case, laser gain occurs in the absence of a population inversion on the lasing transition of the gain medium. Naively, this situation should not occur. Inversionless gain has been suggested as a means of producing laser action in spectral regions where attainment of gain-media population inversion is technologically difficult. We have attempted to elucidate a variety of aspects of two-photon and inversionless gain and lasing using both experimental and theoretical approaches.

SUMMARY OF THE MOST IMPORTANT RESULTS

Two-Photon Lasing. We have provided the first experimental demonstration of continuous-wave two-photon laser action. A novel gain medium consisting of strongly driven two-level atoms was proposed and utilized. For the first time, our experiments demonstrated the bistable operating characteristics of a two-photon laser. In stark contrast to a normal (one-photon) laser, the two-photon laser possesses two stable operating points. One of these is the "off" state. As a result of the stability of the off state, the two-photon laser has been proposed as a high energy device.

What is lasing? Investigation of the various new types of lasing process has lead us to clarify the definition of lasing. We have proposed that laser gain is defined as phase insensitive optical amplification. This definition makes it possible to distinguish lasing processes from the diverse classes of non-linear gain mechanisms.

Pump Bandwidth Effects in Inversionless gain. We have determined that narrowband pump fields lead to substantially larger inversionless gain than can be created with broad bandwidth pump fields. Previous theoretical work had emphasized broad bandwidth pump mechanisms and therefore did not predict maximal gains.

Unexpected Inversions in Three-Level Systems. We have analyzed the dynamics of doubly driven V-type three-level atomic systems and found that certain pairs of atomic states can become inverted even though there is no normal irreversible pathway available for population to enter the upper state of the transition involved. This result is of fundamental and practical interest.

Inversionless Lasing in a Cascade-Type Three-Level Atom. We have performed an experiment in an atomic beam of barium atoms that demonstrates continuous wave lasing in a driven three-level atomic system. Preliminary analysis of the experimental data indicates that the laser emission, observed on the upper transition, was produced in the absence of a population inversion on that transition. Analysis of the experimental results verifies predictions regarding inversionless gain and clarifies its physical origin.

LIST OF ALL PUBLICATIONS AND TECHNICAL REPORTS

Realization of a Continuous-Wave, Two-Photon Optical Laser, D. Gauthier, Q. Wu, S. Morin, and T. W. Mossberg, Phys. Rev. Lett. **68**, 464 (1992).

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Observation of inversionless gain in Cascade-type three-level atom, P. B. Sellin, G. Wilson, K. Meduri, and T. W. Mossberg, (in preparation).

LIST OF PARTICIPATING SCIENTIFIC PERSONNEL

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None